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Analysis of Aircraft Emission Control Parameters

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Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air and Waste Management
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16. ABSTRACT

The impetus for this current analysis of the controlling parameter for aircraft emissions is the ongoing development of international emission regulations through the International Civil Aviation Organization (ICAO). The May 1975 meeting of the Aircraft Engine Emission Study Group (AEESG) of ICAO discussed various approaches to specifying the parameter for controlling aircraft emissions. Appendix A is the record of the meeting pertinent to the controlling parameter. During the May meeting, the viable parameters were narrowed to two basic approaches. Namely, the use of a measure of pollutants normalized by fuel flow and pollutants normalized by thrust or impulse. This report provides an analysis of the merits and disadvantages of these two different approaches.

17. KEY WORDS AND DOCUMENT ANALYSIS

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BACKGROUND

The impetus for this current analysis of the controlling parameter for aircraft emissions is the ongoing development of international emission regulations through the International Civil Aviation Organization (ICAO). The May 1975 meeting of the Aircraft Engine Emission Study Group (AEESG) of ICAO discussed various approaches to specifying the parameter for controlling aircraft emissions. Appendix A is the record of the meeting pertinent to the controlling parameter. During the May meeting the viable parameters were narrowed to two basic approaches. Namely, the use of a measure of pollutants normalized by fuel flow and pollutants normalized by thrust or impulse. This report provides an analysis of the merits and disadvantages of these two different approaches.

DISCUSSION

It was determined by the ICAO study group that the basic parameters for characterization of emission performance for ICAO regulations should have the following characteristics:

a) express effectively the significance of the pollution emitted by a given engine and be usable for planning purposes by providing a reliable indication of the amount of pollutants emitted by a given level of traffic under particular operational conditions;

b) measure the level of technology by the manufacturers and allow a comparison between engines;

c) be measured with enough accuracy by the best techniques and equipment available at the time without involving necessary sophistication; and

d) be expressed in International System of Units (SI Units) to the greatest extent practicable in all calculations involving reduction of emission data and the final reporting of test results.

To determine the extent that the significant parameters comply to these characteristics a detailed evaluation is required.

Characteristics (a) should be given the highest priority in that the parameter not only gives an indication of the amount of pollutant emitted by the engine for planning purposes but is more importantly a <u>limiting</u> parameter. If effective control is to be realized from a regulation, the controlling parameter must indicate the total amount or rate of pollutants

which are permitted, when the aircraft is operated in the critical environment. To achieve this, the parameter should have in part the dimensions of mass pollutant per operation or mass pollutant per time with time related to operation.

To illustrate how a thrust based parameter achieves this, the EPAP parameter can be examined.

$$\text{Airport Pollution} = \sum_{\text{All Aircraft Types}} \left(\frac{\text{Engine Emission}}{\text{Operation}}\right)_{\text{TYPE}} \text{X (No. Engines)}_{\text{TYPE}} \text{X (Operations)}_{\text{TYPE}}$$

The number of engines on a particular type of aircraft can be obtained from many sources, a popular one being Janes, "All the World's Aircraft." The operations for that particular aircraft at a given airport is accurately obtained from the "Official Airline Guide" supplemented with other statistical compilations for unscheduled traffic. This leaves only the engine emissions per operation to be determined. This can be obtained from the EPAP by multiplying the thrust impulse for the particular engine.

$$\frac{\text{Engine Emissions}}{\text{Operation}} = (\text{EPAP})_{\text{Engine}} \text{ X (TOTAL IMPULSE)}_{\text{Engine}}$$

The impulse in a fixed percentage of the rated thrust for a given engine class, except for idle. Rated thrust for any given engine is well known. For the EPAP, idle emissions are determined at the engine manufacturers recommended thrust level. The uncertainty of the idle thrust is the only variable that is not well documented and readily available. For the EPA T2 engine class the impulse can be written as

$$\text{Impulse} = \sum_{\text{Modes}} \text{(Percent Thrust in Mode) X (Rated Thrust) X (Time in Mode)}$$

where the present thrust and time in mode are fixed in the EPAP as:

	Thrust	Time
Idle/Taxi	Manufacturer spec.	26.0 Min
Approach	30%	4.0
Climb Out	85%	2.2
Take Off	100%	0.7

These specified thrust levels are considered representative of a typical operation. As well, the times in mode are considered typical of a major U.S. airport during periods of heavy operations, stimulating concern for air pollutant levels.

From the previous discussion it should be clear that the EPAP parameter or a similar parameter reflecting the total pollutants emitted by an engine over a typical operational cycle can reflect the airport pollution burden. Consideration should now be given to normalizing the pollutant rate with respect to the usefulness or services rendered. Initially one may consider the pollution allowed should be in proportion to the passenger-distance traveled. However, since the problem is related to the airport environment and not the path which the aircraft has come or is departing for, passenger traffic is more representative of the usefulness. To eliminate the variable of load factors, let us consider the passenger traffic to be indicated by the aircraft capacity. Figure 1 clearly illustrates that the total emissions over an operation is proportional to the capacity. Figure 2 and 3 further indicate that the capacity of the aircraft can be represented by the total rated thrust. Thus it is apparent normalizing the aircraft engine emissions by thrust allows the engine to emit pollutants in proportion to its services rendered.

To review the potential for a fuel based parameter (specifically the EI) to achieve the goals of the characteristics (a) the required steps are outlined. The airport pollutant level may be determined from the same initial equation as the thrust based parameter. The deviation from the thrust based computations is in the determination of the engine emissions per operation.

The engine emissions per operation can be determined from the Emission Index in the following manner.

$$\frac{\text{Engine Emissions}}{\text{Operation}} = \sum_{\text{All Modes}} (\text{EI})_{\text{Mode}} \times (\text{SFC})_{\text{Mode}} \times (\text{Impulse})_{\text{Mode}}$$

The computational method for the above relationship has all the same disadvantages as the thrust based parameter but adds the very significant requirement of knowing the EI and SFC values at each of the operational modes of idle-taxi, approach, climb out, and take off. This information is extremely difficult to obtain for a large population of aircraft and would make airport pollutant burden assessments impossible for all but the highly skilled analysist.

Since the EI for a given engine varies with thrust it would be necessary to either specify the limiting value as a function of thrust or limit only the critical modes. The latter approach is understood to be the popular choice. For present day aircraft the critical operational mode for hydrocarbon and carbon monoxide emissions is the taxi-idle cycle. Unfortunately this is not always true of engines utilizing low emission combustors. Figures 4 and 5 illustrate how the EI varies as a function of thrust for a particular developmental emission control concept. Controlling NO_x at takeoff power and HC and CO at idle only will not result in adequate control over the operational cycle.

Thus it is concluded that the EI parameter does not comply with requirement (a). While it may, with proper manipulation, allow the computation of the significance of the pollution it requires an extensive engine data file accessible only to a limited few (major government agencies which have the cooperative support of the various engine manufacturers).

Even though the EI can be used to calculate the engine emissions (assuming other parameters are known) it does not provide a means of limiting the engine emissions. Proponents of the EI parameters argue that emissions can be controlled by limiting EI only, without consideration to engine SFC. The competitive market provides the necessary incentives and the best SFC will be realized. Unfortunately this is not considered to be a valid arguement nor is it expected to materialize. Discussions with a U.S. engine designer revealed that low SFC will continue to be a design goal for cruise conditions only and without the pressures of emission regulations they would not commit significant development funds for reducing idle SFC. However, it is hoped that some improvements in SFC will be realized throughout the operating range with efforts to improve cruise SFC.

The second characteristic (b) requires the emission parameters to be a measure of the level of technology used by the manufacturers and allow a comparison between engines. It is debatable whether either the thrust based or fuel based parameter meets this directly. Assessing the level of technology is a highly complex process and no one parameter does this well for all pollutants.

The emission index is generally accepted as a parameter for evaluating combustion emission performance. However, the EI can not describe the level of technology with a single value nor is it independent of the engine operating cycle. For example, figures 6 and 7 illustrate how the EI for HC, CO and NO_x varies with engine pressure ratio. The EI parameter does have the advantage over the EPAP for comparing <u>combustor</u> performance in that the effects of engine bypass ratio are eliminated.

It should be kept in mind that the level of technology relevant to the engine emissions is that of the engine, and not the combustor alone. For example, high pressure ratio and high bypass ratio engines are characteristically the more advanced technology (for high speed subsonic aircraft). Since engine emissions are dependent upon combustor technology and engine cycle technology it is only reasonable that a parameter which incorporates both aspects would be desired for indicating the level of technology.

In the short term the significance of the incorporation of the engine operating cycle into the controlling parameters has limited value because it is highly impractical to modify the operating cycle for an existing engine. The importance of the cycle dependent emission parameter is to influence the design of future engines, assuring proper consideration to environmental needs. For the existing engines, the reduction in emissions are primarily the responsibility of the combustor design. With the EPAP as a controlling parameter there will result a range of sophistication for combustors meeting the needs of a variety of engines. The responsibility for determining the technical feasibility of reducing emissions and establishing equitable limits belongs to the controlling organization. These limits can be established equally well with the two contending parameters.

The third characteristic (c) requires the parameter "be measured with enough accuracy by the best techniques and equipment available at the time without involving unnecessary sophistication." By comparing the thrust based parameter (e.g. EPAP) computations and the fuel based parameter (e.g. EI) computations, it will be realized that the measured parameters are identical for the two approaches.

The EPAP is computed from the emission test data as follows:

$$\text{EPAP}\left(\frac{\text{Pounds pollutant}}{\text{1000 pounds-thrust hours}}\right) = \left(\frac{\text{Sum of pollutant mass/mode of each mode}}{\text{Sum of work output of each mode}}\right)$$

The pollutant mass and work output per mode are obtained from:

pollutant mass/mode = pollutant emission rate X time in mode

work output of each mode = power (in 1000 pounds thrust) X time in mode

The emission rates for each mode are determined from measurements of concentration of the pollutants in the exhaust and a computation method which requires the knowledge of fuel flow rates. For example the hydrocarbon emission rate for each mode is determined from:

$$\text{HC emission rate} = \frac{M_{HC}\frac{(HC)}{10^4}F}{(M_c + aM_H)\left(\frac{(CO)}{10^4} + (CO_2) + \frac{(HC)}{10^4}\right)}$$

where HC mass/mode = total mass of hydrocarbon emissions in pounds emitted during an operational mode.

HC emission rate - pounds/hour of exhaust hydrocarbons emitted in an operational mode.

M_{HC} = molecular weight of methane, M_{HC} = 16.04.

M_C = atomic weight of carbon.

M_H = atomic weight of hydrogen, $M_H = 1.008$.

a = atomic hydrogen-carbon ratio of fuel.

For each operating mode

(HC) = concentration of hydrocarbons in the exhaust sample in parts per million carbon equivalent, i.e., equivalent propane x 3.

(CO) = concentration of carbon monoxide in the exhaust sample in parts per million by volume.

(CO_2) = concentration of CO in the exhaust sample in volume percent.

F = mass rate of fuel flow in pounds per hour.

TIM = time in mode as specified in paragraph (d) of this section, divided by 60 to yield time in mode in hours.

Similar procedures are used for the carbon monoxide and oxide of nitrogen emissions.

The Emission Index EI is computed from the same equation as the pollutant emission rate but the fuel flow term is transposed. For example for HC emissions:

$$EI = \frac{\text{HC rate}}{F} = \frac{M_{HC} \dfrac{(HC)}{10^4}}{(M_c + aM_H)\left[\dfrac{(CO)}{10^4} + (CO_2) + \dfrac{(HC)}{10^4}\right]}$$

Thus, the measurement methods are identical for both parameters.

The fourth and final characteristic (d) is that the parameters be expressed in International System of Units (SI units). This requirement causes no difficulties with either of the contending parameters.

FIGURE 1
EMISSIONS AS A FUNCTION OF
MEAN AIRCRAFT CAPACITY

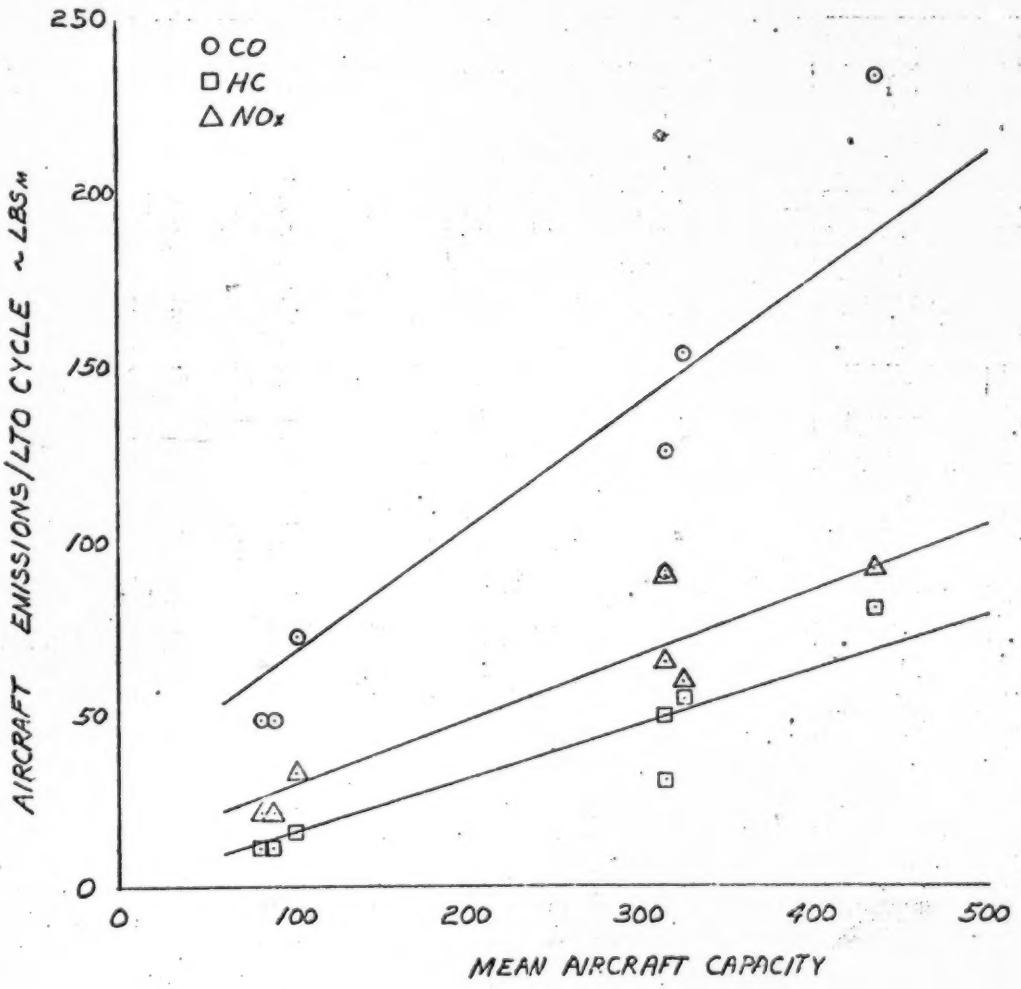


FIGURE 2
EMISSIONS AS A FUNCTION OF
THRUST/AIRCRAFT

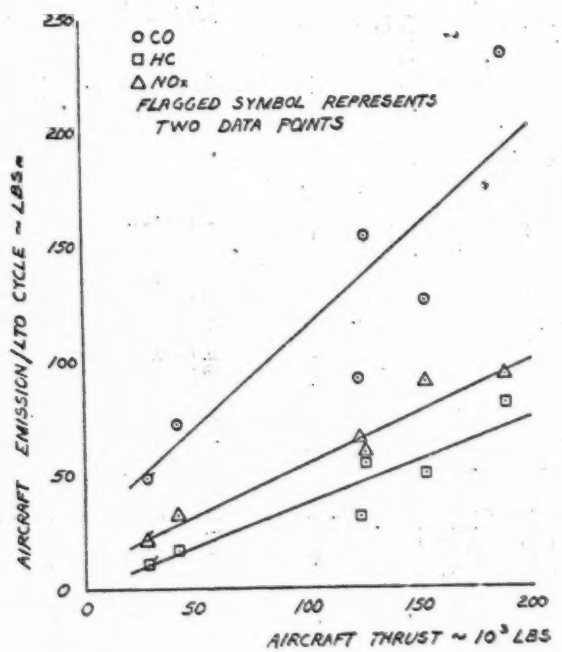
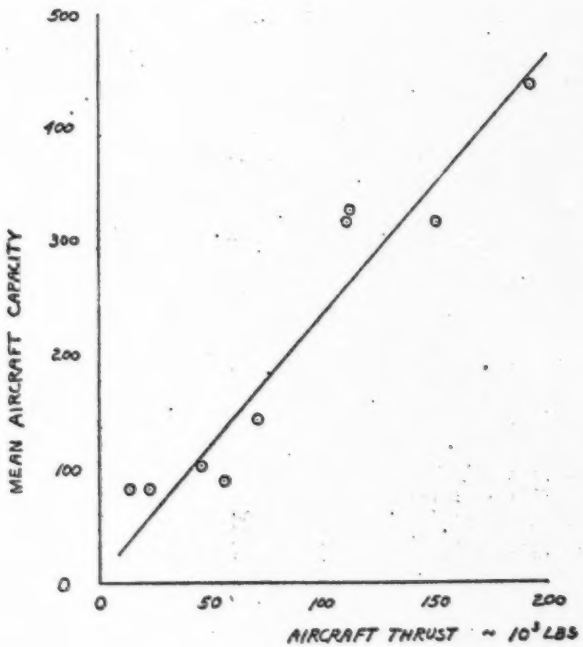
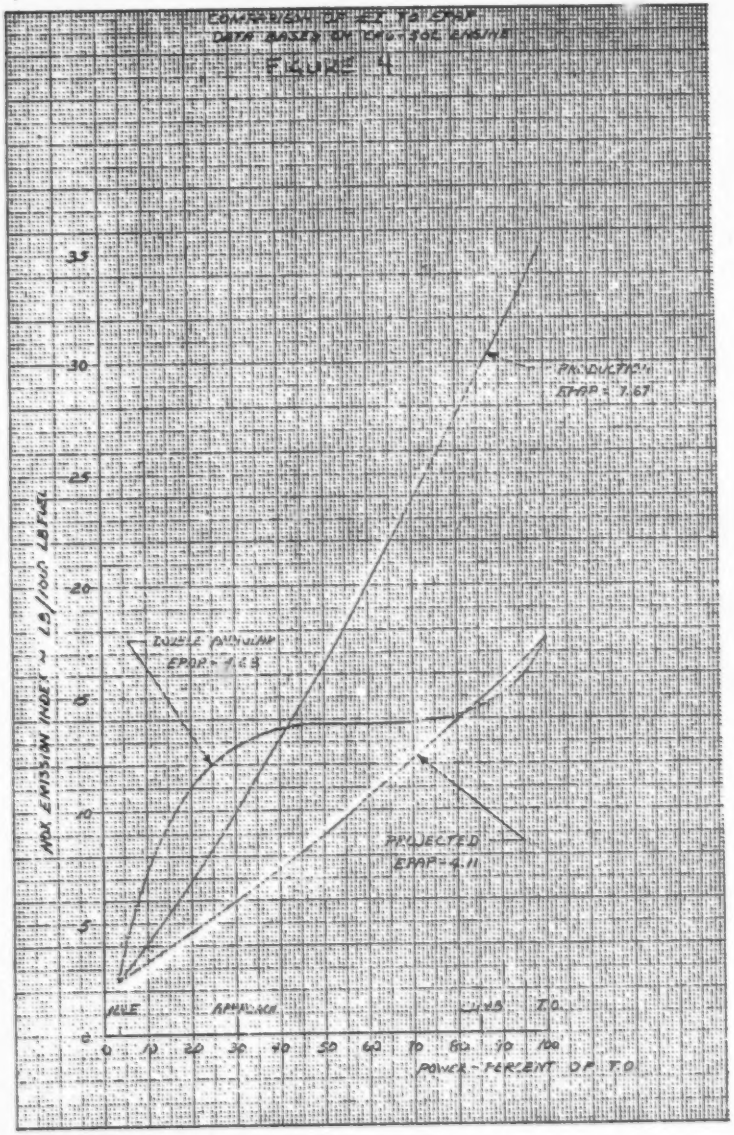
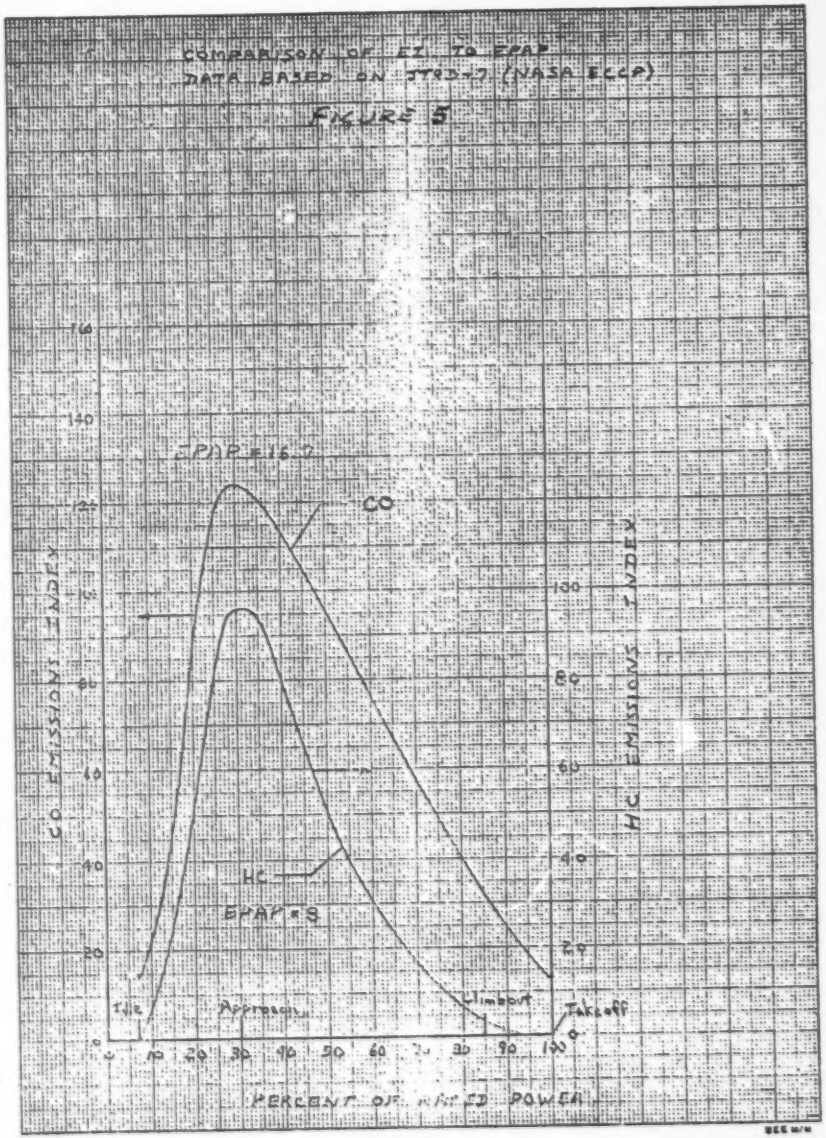


FIGURE 3
AIRCRAFT CAPACITY AS A FUNCTION OF
MEAN AIRCRAFT THRUST




COMPARISON OF EI TO EPAP
DATA BASED ON CFM-56 ENGINE
FIGURE 4
NOx EMISSION INDEX ~ LB/1000 LB FUEL
35
30
25
20
15
10
5
0
PRODUCTION
EPAP = 7.67
DOUBLE ANNULAR
EPAP = 7.6
PROJECTED
EPAP = 4.11
IDLE
APPROACH
CLIMB
T.O.
0 10 20 30 40 50 60 70 80 90 100
POWER - PERCENT OF T.O.


COMPARISON OF EI TO EPAP
DATA BASED ON JT8D-17 (NASA ECCP)
FIGURE 5
EPAP = 16.7
CO
HC
EPAP = 8
CO EMISSION INDEX
HC EMISSIONS INDEX
160
140
120
100
80
60
40
20
0
80
60
40
20
0
Idle
Approach
Climbout
Take-off
0 10 20 30 40 50 60 70 80 90 100
PERCENT OF RATED POWER

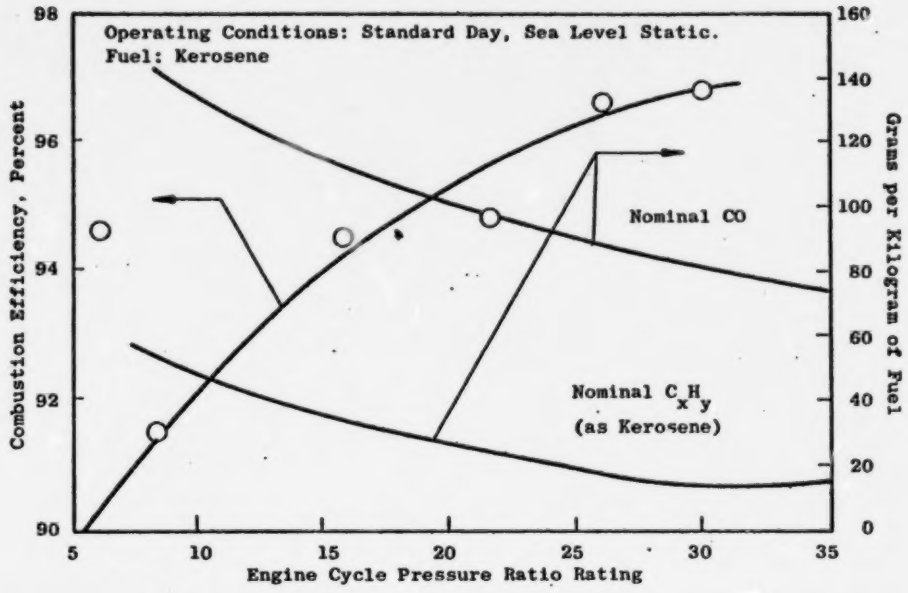


Figure 6* Combustion Efficiency, C_xH_y Emissions and CO Emissions Characteristics of Various General Electric Aircraft Turbine Engines at Ground Idle Power.

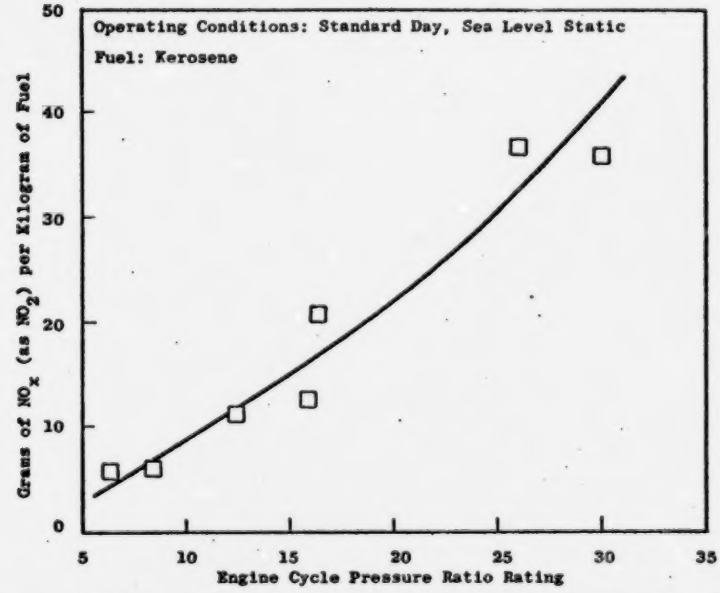
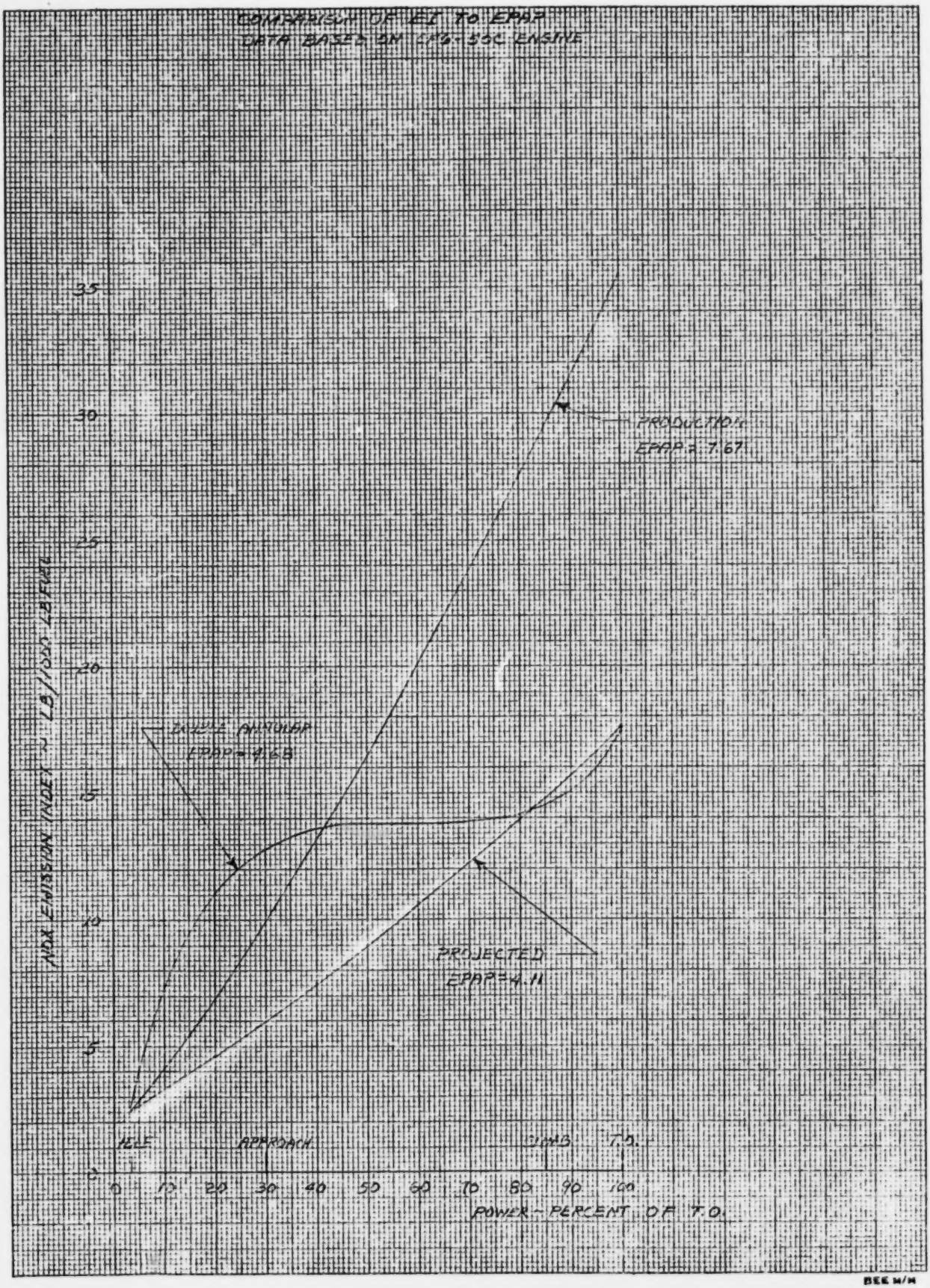
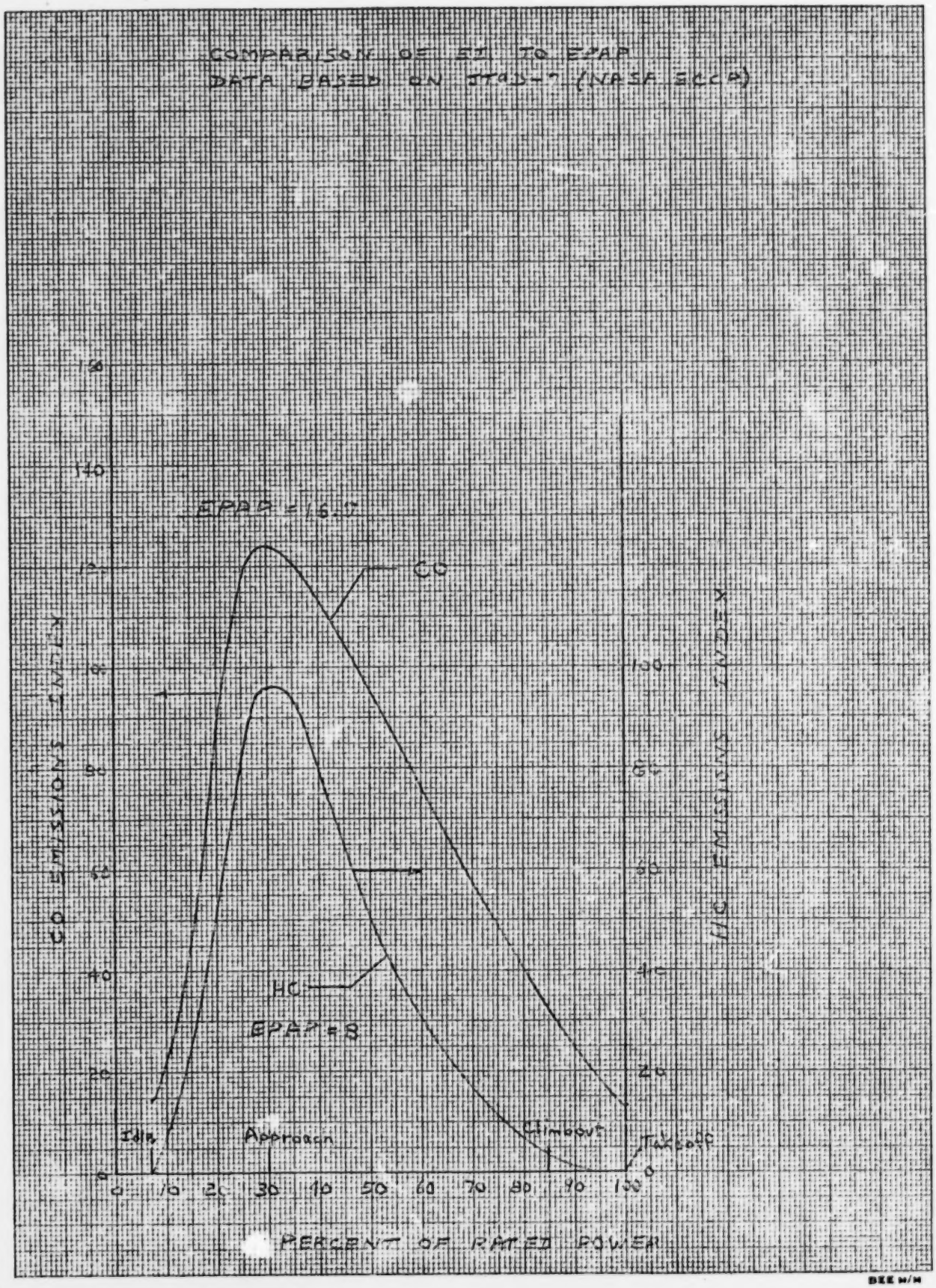


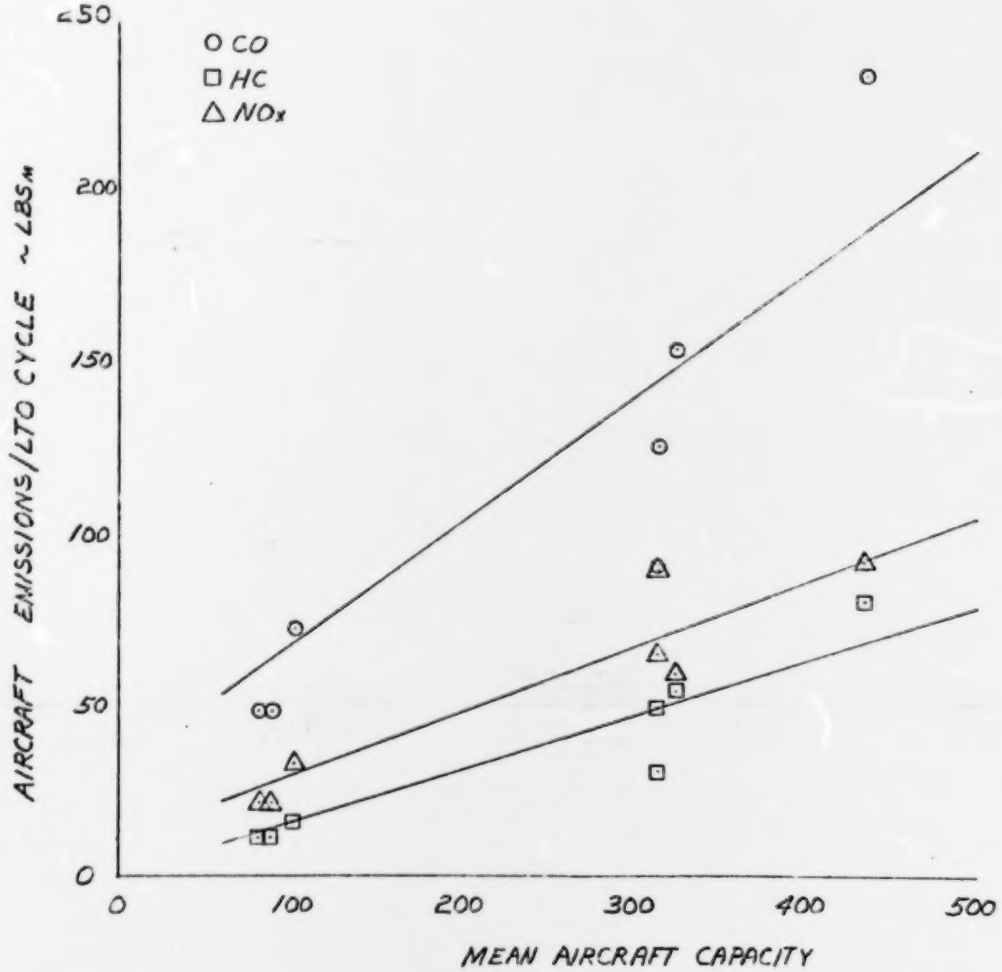
Figure 7* NO_x Emissions Characteristics of Various General Electric Aircraft Turbine Engines at Take-off Power.

* ICAS PAPER 74-31 "TECHNOLOGY FOR THE REDUCTION OF AIRCRAFT TURBINE ENGINE POLLUTANT EMISSIONS" DONALD W. BAHR & CLIFFORD C. GLEASON GENERAL ELECTRIC, CINCINNATI OHIO U.S.A.

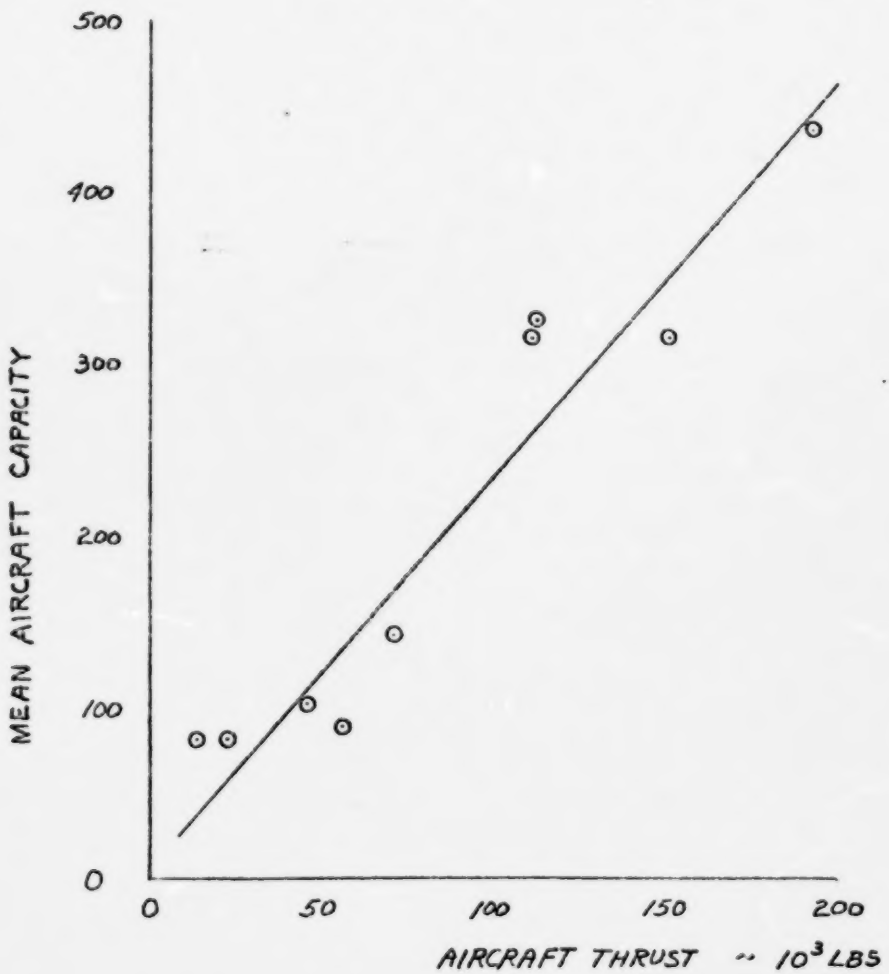

COMPARISON OF EI TO EPAP
DATA BASED ON CFG-56C ENGINE
NOx EMISSION INDEX - LB/1000 LB FUEL
35
30
25
20
15
10
5
0
PRODUCTION
EPAP = 7.67
SINGLE ANNULAR
EPAP = 4.68
PROJECTED
EPAP = 4.11
IDLE
APPROACH
CLIMB
T.O.
0
10
20
30
40
50
60
70
80
90
100
POWER - PERCENT OF T.O.
BEE M/M


COMPARISON OF EI TO EPAP
DATA BASED ON JT8D-7 (IVASE ECC#)
EPAP = 16.0
CO
HC
EPAP = 8
EMISSIONS INDEX
H/C EMISSIONS INDEX
Idle
Approach
Climbout
Takeoff
PERCENT OF RATED POWER
0
10
20
30
40
50
60
70
80
90
100
120
140
160
180
200
DEE M/M

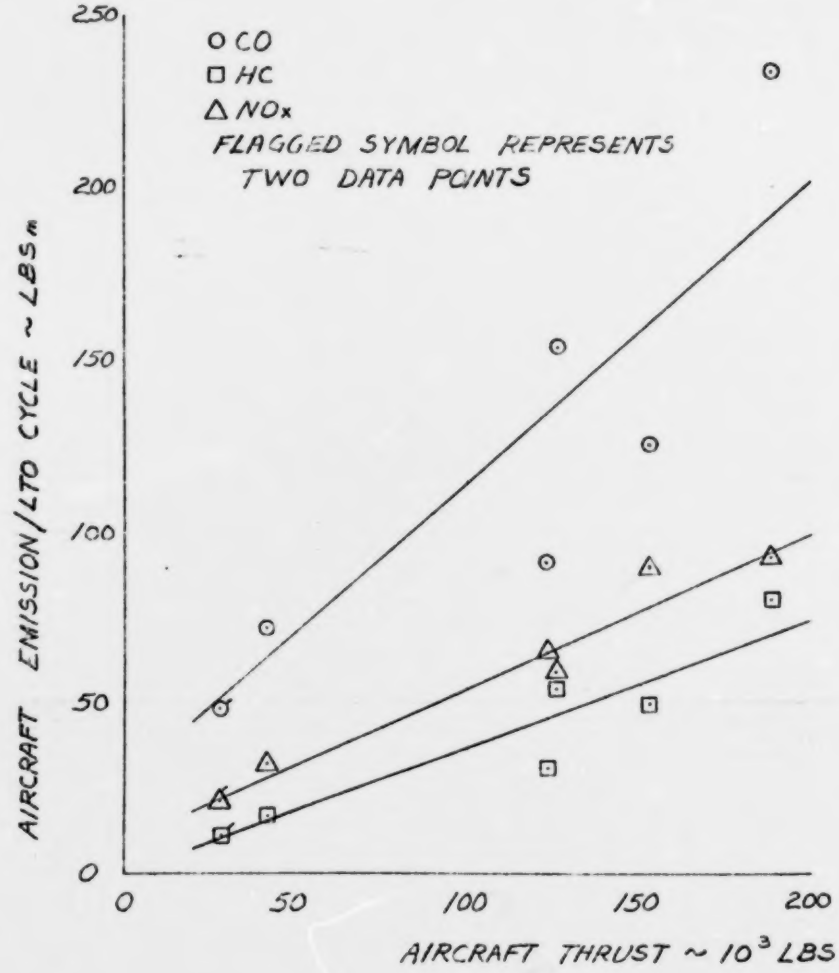
EMISSIONS AS A FUNCTION OF
MEAN AIRCRAFT CAPACITY



AIRCRAFT CAPACITY AS A FUNCTION OF
MEAN AIRCRAFT CAPACITY



EMISSIONS AS A FUNCTION OF
THRUST/AIRCRAFT



APPENDIX A

16

ICAO AEESG MEMORANDUM NO. 11 30MAY1975
(IN PART, PAGES B-12)

3.3.5 Parameters for characterization of emission performance

3.3.5.1 The basic parameters for characterization of emission performance should have the following characteristics:

a) express effectively the significance of the pollution emitted by a given engine and be usable for planning purposes by providing a reliable indication of the amount of pollutants emitted by a given level of traffic under particular operational conditions;

b) measure the level of technology used by the manufacturers and allow a comparison between engines;

c) be measured with enough accuracy by the best techniques and equipment available at the time without involving unnecessary sophistication; and

d) be expressed in International System of Units (SI Units) to the greatest extent practicable in all calculations involving reduction of emission data and the final reporting of test results.

3.3.5.2 The gaseous emission data could be expressed as parameters in the following form:

a) concentration (parts per million by volume);

b) pollutant mass flow;

c) pollutant mass flow/fuel mass flow (emission index);

d) mass pollutant per reference LTO cycle;

e) mass pollutant per reference LTO cycle/characteristic thrust; and

f) mass pollutant per reference LTO cycle/characteristic fuel mass.

3.3.5.3 These parameters were described as follows:

a) Concentration:- It was generally agreed that the determination of concentration was a first step in the measurement process, but that it is not a useful parameter to describe the emission performance of an engine.

b) Pollutant mass flow:- This parameter is of great use in actual emission impact calculations and is therefore required from engine manufacturers irrespective of the unit used for certification purposes.

c) Pollutant mass flow/fuel mass flow:- Otherwise known as the emission index (EI) for the mode; this parameter is a simple measure of emission performance especially in comparison with other emission sources and provides information on the technological level of the combustor design.

d) Mass pollutant per reference LTO cycle:- This gives a measure of the total nuisance created by an engine during the reference LTO cycle.

e) Mass pollutant per reference LTO cycle/characteristic thrust:- This parameter relates the mass pollutant emitted during the LTO cycle to the characteristic thrust. It combines in a single number the effects of:

1) the choice of an engine cycle; and

2) the use of a given combustor technology level.

f) Mass pollutant per reference LTO cycle/characteristic fuel mass cycle:- This parameter is similar to the EI but integrated over the whole LTO cycle, thus reducing the index to a single figure. It characterizes mainly the combustor technology and removes the effects of specific fuel comsumption.

3.3.5.4 After examining the relative merits of the above parameters, it was concluded that the results of engine emission tests at each specified power setting should be reported by the manufacturer in terms of mass pollutant per unit time and mass pollutant per unit fuel burned. These were considered essential for the preparation of environmental impact data for different aerodromes and for the purpose of computation of the various parameters mentioned in 3.3.5.2 above. It was agreed that the following engine data should be supplied by the manufacturer in each case:

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Power setting	Idle	Approach	Climb	Take-off
Thrust Rating	X	X	X	X
Fuel Flow	X	X	X	X
Emission rate g/sec	X	X	X	X
Emission index g/kg fuel	X	X	X	X
Gross Emission per reference LTO cycle		X		

3.3.5.5 The Group considered that all the possible regulatory parameters (see para 3.3.5.2) could be divided into two different categories as follows:

a) the first category which comprises the parameters c) and f) is considered to be an indicator of the combustor cleanliness; and

b) the second category which comprises the parameters b), d) and e) characterizes the resulting impact of the pollutant emitted.

The main characteristics and properties of these two categories of parameters are presented and commented on hereunder.

3.3.5.5.1 First category - combustor cleanliness parameters

Parameters of this type have the characteristics of "emission index" and determine the cleanliness of the combustor technology without involving the engine specific fuel consumption (SFC). The advocates of this approach stated that:

a) by requiring all regulated engines to employ the same level of combustor technology without reference to SFC, they avoid imposing unnecessary constraints on the engine cycle additional to those already acting in favour of low emissions (through reduced fuel flow) because of the requirements for reduced noise and SFC, which are most unlikely to be relaxed in the foreseeable future: by contrast, parameters involving SFC require assumptions to be made about the engine cycle when determining regulatory levels for future engines which restrict the choice of engine cycles considerably;

b) it is not in any case self-evident that additional pressures for reduced fuel consumption will reduce total emissions impact beneficially, because some methods of reducing SFC, while resulting in a reduction of HC and CO emissions, will simultaneously result in a rapid increase in NO_x;

c) when considering newly manufactured engines of existing types, a parameter involving SFC has to be fixed at a level high enough to allow for the engines of highest SFC among existing types (which means that the other engines of lower SFC can have dirtier combustors than they need have), or the level has to be lower, which means allowing a number of special cases, or the prohibition of further manufacture of the engines of higher SFC;

d) parameters of the emission index type permit the same regulatory levels to be used for more than one engine class, which will be particularly helpful with respect to Classes II and V. Furthermore, it helps to demonstrate to the general public that engines of different designs are being required to employ the same standard of low pollution combustor technology.

3.3.5.5.2 Second category - impact of the pollutant emitted

The parameters of this type intend to meet the requirements a) and b) of paragraph 3.3.5.1 and reflect the total amount of a pollutant emitted by an aircraft in the vicinity of the aerodrome. The advocates of this approach stated that:

a) the use of parameters of this type, which are a product of the combustor cleanliness and engine SFC, make it possible to guarantee directly a limit to the total pollutant production. To reach the regulatory limits all engine design factors which could influence the level of emissions must be taken into consideration. If only one variable, such as combustion efficiency is controlled, the overall engine emissions would then be controlled by the selection of other design variables such as engine by-pass ratio or pressure ratio, which directly influence fuel consumption. The type of parameters which are a product of both combustion cleanliness and engine fuel consumption represent an incentive to the engine designer to achieve the lowest overall engine emissions level;

b) the competitive market and other pressures on designers of engines give him strong incentives to minimize fuel consumption, particularly at engine cruise power settings. However, available data on a number of current engines shows a very wide range of exhaust emission levels at idle power settings. This suggests that an emissions parameter which includes the effects of fuel consumption will represent a meaningful stimulus to achieve low emissions and low fuel consumption at idle power setting, which has been regarded in the past by industry as an "off-design" point;

c) with a parameter of this type, the individual manufacturer within a regulated industry is given wide flexibility in choosing the optimum combination of techniques to achieve the regulatory limits, when developing a new engine design. By using a regulatory parameter which specifies the results of an engine emissions reduction programme in terms of the performance of a complete engine or vehicle, a more defensible and equitable (industry-wide) approach is provided, which is consistent with normal competitive processes; and

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d) to employ an expression of engine emission behaviour, which is based only on combustor technology, can be considered misleading by the general public, who will not readily understand why different engines meeting the same standard and having the same thrust have widely different total emission behaviour.

3.3.5.5.3 In summary, an emission index parameter is independent of the engine SFC and regulations based on it assume that commercial competitive pressures will lead to reduced fuel consumption with future engines. A parameter of the second category in effect adds a further direct incentive to reducing SFC by involving assumptions about the cycles to be used in future engines.

3.3.5.6 With regard to smoke emission measurements, the filtration method [expressed in terms of Smoke Number (SN)] specified in the US EPA Regulations was considered to be generally acceptable. However, a disadvantage of this procedure is the excessive time required at take-off thrust. It was felt that the ICAO procedure should not require a time exceeding five minutes at maximum thrust. The alternative method would be one using an optical technique in which measurements are made directly by an instrument with a read-out expressed in Photo Smoke Units (P.S.U.) or Hartridge Smoke Units (H.S.U.) depending on the specific technique used. Work is in progress in the IMT Sub-group to determine whether a satisfactory correlation between these methods can be obtained. If it can, the Group considered it desirable that both methods should be allowed.

3.3.6 Maximum levels

The Group examined a methodology for choosing the pollution limits which would comply with the requirements presented in paragraph 3.1 and which would require an equitable technological effort from all manufacturers of the different engine types described in paragraph 3.2.1. It was agreed that the limits should be based on a complete description of the technological characteristics controlling the exhaust emission of the engines. These characteristics are essentially the emission indices, examples of which are given in Appendix B. The Study Group agreed that the NO_x emission index may be considered, for a given level of technology, as a function of the combustor entry temperature. It was also agreed to investigate further the most appropriate parameter to characterize the CO and HC emission indices. In order to prepare the final proposal, a "Methodology Sub-group" was set up. This Sub-group will collect and analyse the available technological information and present its results in a form suitable for direct comparison. The Study Group agreed that the emission indices (which will allow calculation of the regulatory levels) should be based on experimental data and on expected improvements in future technology consistent with reasonable economical penalties.

3.3.7 Method of measurement and analysis

The Group reviewed the Report of the First Meeting of the Instrumentation and Measurement Technology (IMT) Sub-group which met in October 1974. It was noted that the Sub-group found the methods specified by the US EPA and SAE in general to be acceptable but there was considerable disagreement about the validity of the specifications in some areas which could only be resolved by further research. A number of tasks had been allocated to members of the Sub-group, but no results were

yet available. Members of the AEESG agreed to stimulate the efforts of Sub-group members from their States. It was agreed that the work of the Sub-group should result in a self-contained statement of methods of pollutant measurement and analysis which would form a part of any ICAO recommended certification scheme. It was further noted that the Sub-group should take due account of the methods used by engine manufacturers for the reduction of test data to reference conditions.

3.3.8 Applicability of the scheme

3.3.8.1 For the reasons given in 2.2 the Group felt it preferable at this time not to consider an international certification scheme for engines in the "obsolete" and "in use" categories [categories a) and b) in 3.2.2]. It was noted that at least one State with pollution problems at particular aerodromes has already taken national action which involves the modification of "in use" engines.

3.3.8.2 With regard to the "newly certificated" and "newly manufactured" engines [categories c) and d) in 3.2.2], it was recognized by the Group that applicability dates for the regulations should not be the same. It was also recognized that the levels for the two categories could not be the same since the benefits of advanced technologies which could be incorporated in new designs could not always be applied to existing designs. The Group agreed that it was desirable to have engine emission requirements for both categories as soon as practicable. However, the following applicability dates for a certification scheme were tentatively agreed upon:

	Newly Certificated Engines	Newly Manufactured Engines
Fuel Venting	Adoption date of the Specifications by ICAO	Adoption date of the Specifications by ICAO
Smoke	"	1 January 1979
Carbon Monoxide and Hydrocarbons	"	"
Oxides of Nitrogen	"	"

3.3.9 Framework for a scheme

Based on the above considerations a framework for a scheme for exhaust emissions certification of Class I engines was developed and this is included in Appendix C to this Report.

3.4 Certification of engines other than Class I engines

It is considered that the general approach to the certification of Class I engines could be used as a basis for the development of certification requirements for other classes of engines.

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